

UNITED STATES PATENT APPLICATION

FOR

**PATTERNED SEED LAYER SUITABLE FOR ELECTRON-  
EMITTING DEVICE AND ASSOCIATED FABRICATION METHOD**

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**PATTERNED SEED LAYER SUITABLE FOR ELECTRON-  
EMITTING DEVICE, AND ASSOCIATED FABRICATION  
METHOD**

5    CROSS REFERENCE TO RELATED APPLICATION

          This is related to Chang et al., co-filed U.S.  
patent application Ser. No.:           .attorney  
docket No.: CDDC/CHC/001. To the extent not repeated  
herein, the contents of Chang et al., are incorporated  
10    herein by reference.

FIELD OF USE

          This invention relates to carbon based  
field emitters. More particularly, this  
15    invention relates to the structure and  
fabrication of an electron-emitting device in  
which electrically conductive seed material is  
situated between electron-emissive elements, on  
one hand, and emitter electrodes, on the other  
20    hand, and which is suitable for use in a flat-  
panel display of the cathode-ray tube ("CRT")  
type.

BACKGROUND

25       A flat-panel CRT display basically consists  
of an electron-emitting device and a light-  
emitting device that operate at low internal  
pressure. The electron-emitting device,  
commonly referred to as a cathode, contains  
30    electron-emissive elements that emit electrons  
over a wide area.

          The emitted electrons are directed towards  
light-emissive elements distributed over a  
35    corresponding area in the light-emitting  
device. Upon being struck by the electrons,

the light-emissive elements emit light that produces an image on the viewing surface of the display.

5        When the electron-emitting device operates according to field-emission principles, electrically conductive seed material is commonly placed in series with the electron-emissive elements to gate the magnitude of  
10       current flow through the electron-emissive elements. Fig. 1 illustrates a conventional field-emission device, that so utilizes the seed material.

15       In the field emitter of Fig. 1, electrically seed (catalyst) layer 25 overlies emitter electrodes 15 provided on baseplate 10. Gate (or gate) electrodes 40, one of which is depicted in Fig. 1, are situated on dielectric  
20       layer 35 and passivation layer 30 situated on the gate layer 40 and cross over emitter electrodes 15. Electron-emissive elements 45 are situated on emitter conductive layer 25 in openings 50 through dielectric layer 35 and are  
25       exposed through corresponding openings 50 in gate electrodes 40.

Seed layer 25 is typically a blanket layer. That is, seed layer 25 extends in a continuous  
30       manner over the emitter electrodes 15 and the intervening portions of baseplate 10. Consequently, each electron-emissive elements 45 is electrically coupled through seed layer 25 to each other element 45. In the prior art  
35       device shown in Fig. 1, the electron emissive elements are a group carbon based filaments.

The catalyst layer 25 is normally a conductive material that is layer 25 effectively does not electrically isolate each  
5 group of elements 45 from each other. Thus, there could be a kind of intercoupling of electrons emissive elements 45 through layer 25. That means electron emission from a group of elements 45 would have an effect on the  
10 other group of element 45. A degradation of one group of elements 45 usually means other groups of elements 45 would have an effect on the emitting of other groups of element 45.

15 The intercoupling of the electron emission elements 45 also causes an undesirable process of non-uniformity of deposition, patterning and etching of the electron emission elements 45. The differences in the uniformity of the  
20 electron emission elements creates a situation where the elements 45 have different threshold voltage for electron emission. Thus, most of elements 45 would not start to emit electrons at the same time.

25 Because of the intercoupling provided by catalyst layer 25, a few of the groups of the elements 45 that would have low value of voltage could become the primary source of  
30 electron emitting for the entire group in the display device rather than emitting electrons from most of the groups of elements 45. Thus, those elements 45 that act as a primary electron emitting source could result in the  
35 emitter degradation.

It is therefore desirable to have a seed layer upon which the carbon based emitter electrons can be formed and treated that reduces the number and/or complexities of steps conventionally required to fabricate the field emitter structure.

It is desirable to have a conductive seed layer that provides conductivity at selected areas along baseplate 10 but does not itself electrically interconnect these areas. In this regard, electron-emissive elements 45 at each location where one gate electrode 40 crosses over one emitter electrode 15 operate as a unit and need not be conductively coupled.

It is also desirable to configure the seed layer in such a way that underlying emitter electrodes be externally electrically accessible along their upper surfaces without the necessity of performing a separate etching operation to cut openings through the seed layer. Furthermore, it is preferable to provide a suitable pattern in the seed layer without employing any additional masking steps beyond those used for patterning other components in the field emitter.

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## GENERAL DISCLOSURE OF THE INVENTION

The present invention furnishes an electron-emitting device having a seed layer patterned to meet the foregoing needs. The present seed layer contains multiple laterally separated sections situated between electron-emissive elements, on one hand, and emitter electrodes, on the other hand. The sections of the seed layer are spaced apart along each emitter electrode.

The seed sections underlie gate electrodes of the present electron-emitting device in various ways. In one general embodiment, the seed sections are basically configured as seed strips situated below the gate electrodes. Each seed strip is sufficiently long to extend over at least one, typically all, of the emitter electrodes.

In another general embodiment of the seed layer, the seed sections are basically configured as seed portions spaced apart below each gate electrode and above each emitter electrode. As viewed in the vertical direction, the seed portions are roughly centered at the locations where the gate electrodes cross over the emitter electrodes. As contrasted to the first-mentioned embodiment in which each seed strip extends over two or more of the emitter electrodes, each seed portion in this embodiment extends over only one of the emitter electrodes.

To manufacture an electron-emitting device that employs the seed layer of the invention, a

structure is typically first provided in which a gate electrode overlies a dielectric layer that overlies an electrically seed layer overlying an emitter electrode.

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Electron-emissive elements are situated in a composite opening extending through the gate electrode and dielectric layer in the structure so that the electron-emissive element overlies the seed layer above the emitter electrode. Creation of the seed sections involves removing portions of the seed layer located generally below spaces situated to the sides of the gate electrode.

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Again, there is no need to perform an extra masking step to provide this initial patterning to the seed layer. The net result is that the desired pattern can be provided in the seed layer without increasing the number of masking steps.

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In some applications, a separate masking step may be employed in providing the requisite pattern in the seed layer. Use of a separate masking step may arise as a matter of process convenience or due to overall processing constraints.

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### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-sectional view of the  
core of a conventional electron-emitting  
5 device;

Figs. 2 is a cross-sectional structural  
view of the core of an electron-emitting device  
provided with a seed layer patterned in  
10 accordance with the invention;

Figs. 3a - 3e are cross-sectional  
structural views representing steps in  
manufacturing an embodiment of the electron-  
15 emitting device of Fig. 2 according to the  
invention; and

Fig. 4 is a cross-sectional structural view  
of another embodiment of the core of an  
20 electron-emitting device provided with a seed  
layer patterned in accordance with the present  
invention.

Like reference symbols are employed in the  
25 drawings and in the description of the  
preferred embodiments to represent the same, or  
very similar, item or items.



## DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the present invention, a conductive seed layer connected in series with electron-emissive elements of an electron-emitting device is patterned into multiple sections laterally separated along each emitter electrode in the device. The electron emitter of the invention typically operates according to field-emission principles in producing electrons that cause visible light to be emitted from corresponding light-emissive phosphor elements of a light-emitting device. The combination of the electron-emitting device, often referred to as a field emitter, and the light-emitting device forms a cathode-ray tube of a flat-panel display such as a flat-panel television or a flat-panel video monitor for a personal computer, a lap-top computer, or a workstation.

In the following description, the term "electrically insulating" (or "dielectric") generally applies to materials having a resistivity greater than  $10^{10}$  ohm-cm. The term "electrically non-insulating" thus refers to materials having a resistivity below  $10^{10}$  ohm-cm. Electrically non-insulating materials are divided into (a) electrically conductive materials for which the resistivity is less than 1 ohm-cm and (b) electrically resistive materials for which the resistivity is in the range of 1 ohm-cm to  $10^{10}$  ohm-cm. These categories are determined at an electric field of no more than 1 volt/ $\mu$ m.

Examples of electrically conductive materials (or electrical conductors) are metals, metal-semiconductor compounds (such as metal silicides), and metal-semiconductor eutectics. Electrically conductive materials also include semiconductors doped (n-type or p-type) to a moderate or high level. The semiconductors may be of the monocrystalline, multicrystalline, polycrystalline, or amorphous type.

Electrically resistive materials include (a) metal-insulator composites such as cermet, (b) certain silicon-carbon compounds such as silicon carbide and silicon-carbon-nitrogen, (c) forms of carbon such as graphite, amorphous carbon, and modified (e.g., doped or laser-modified) diamond, and (d) semiconductor-ceramic composites. Further examples of electrically resistive materials are intrinsic and lightly doped (n-type or p-type) semiconductors.

A transverse profile is a vertical cross section through a plane perpendicular to the length of an elongated region. The row direction in a matrix-addressed field emitter for a flat-panel display is the direction in which the rows of picture elements (pixels) extend. The column direction is the direction in which the columns of pixels extend and runs perpendicular to the row direction.

Fig. 2 illustrates the core of a matrix-addressed field emitters that contain an emitter conductor patterned into conductor

strips in a vertically aligned manner according to the invention. The cross sections of Fig. 2 is taken through perpendicular planes.

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The field emitter of Fig. 2 is created from a flat electrically insulating baseplate (substrate) 100 typically consisting of glass having a thickness of approximately 1 mm. To  
10 simplify the pictorial illustration, baseplate 100 is shown in the perspective view of Fig. 2.

A patterned electrically conductive seed layer 120 is disposed on a resistor layer 115  
15 which is in turn disposed on the emitter electrode 110. The seed layer 120 provides a seed platform on which the electron emission elements of the present invention are built.

20 In one embodiment of the present invention, the patterned strips of seed layer 120 are typically aligned with the gate layer 130 and situated in openings 145 in a way to isolate groups of the electron emission elements 140  
25 from each other. Isolating the group of electron emission elements ensures that a defect in one group does not affect the emission quality of the other groups.

30 Fig. 3A depicts a partial cross-sectional representation of the field emitter structure 1 of one embodiment of the present invention. The method fabricating the field emitter structure 1 generally includes providing a bas  
35 plate 100 and disposing thereon a plurality of emitter electrodes. The group of generally

parallel emitter electrodes 110 are situated on baseplate 100.

5 Emitter electrodes 110 extend in the row direction and constitute row electrodes. As shown in Fig. 3A, each emitter electrode 110 has a transverse profile roughly in the shape of an upright isosceles trapezoid. This profile helps improve step coverage of layers  
10 formed above emitter electrodes 110.

Emitter electrodes 110 typically consist of aluminum, molybdenum, or chromium, or an alloy  
15 of any of these metals. In the case of aluminum, emitter electrodes 110 are typically 0.1 - 0.5  $\mu\text{m}$  in thickness.

20 In one embodiment of the present invention, the emitter electrode 110 is deposited in-situ by a number of well known deposition methods of the prior art. In one embodiment. Sputter deposition may be used. In another embodiment, a form of evaporation deposition may be used.

25 Upon deposition of the emitter electrode 110, a photo-resistive material (PR) is coated on the emitter electrode 110. The photo-resistive coating is then soft baked. After coating and baking, the photo-resistive  
30 material is exposed according to a designed patterned and developed. After developing the photo-resist material, the photo-resist material is hard baked and the part of the emitter electrode which is opened through the  
35 PR after being developed is etched away and stripped away.

The emitter electrode 110 is patterned by a number of photolithographic processes well known in the art accordingly. Applicable  
5 etching methods include wet etching. Remaining PR maskant is stripped off by methods well known in the art.

Fig. 3B depicts a partial cross-sectional  
10 representation of structure 1 having undergone further steps of deposition of a resistor layer 115. The resistor layer 115 is then fabricated by deposition of a layer of resistive material  
15 on the emitter electrode layer 110 and remaining surfaces of the glass 100 uncovered by the emitter electrode 110 material.

In one embodiment of the present invention, the resistor layer 115 is deposited by a number  
20 of well known methods in the art. In one embodiment, deposition of the resistor layer 115 is accomplished by plasma enhanced chemical vapor deposition (PECVD) method.

25 Upon deposition of the resistor layer 115, a photo-resistive material(PR) is coated on the resistor layer 115. After coating, the PR is soft baked, exposed and developed. The PR is subsequently hard baked and dry etched to  
30 conform to the contours of the surface of the glass 100. Remaining PR maskant is stripped by methods well known in the art.

Fig. 3C depicts a partial cross-sectional  
35 representation of structure 1 having undergone further steps of depositing a conductive seed

layer 120. A patterned electrically conductive seed layer consisting of a group of laterally separated generally parallel strips 120 is disposed on top of emitter electrodes 110 and resistor layer 115.

In one embodiment of the present invention, the seed layer 120 provides an enhanced seeding platform on which to deposit or coat the electron emission elements of the invention. Conductive seed strips 120 extend in the column direction and are spaced apart along each emitter electrode 110. Each seed strip 120 extends over portions of electrodes 110.

Consequently, strips 120 overlie laterally separated parts of each electrode 110. Strips 120 are vertical conductors in that current flows through strips 120 largely in the vertical direction between electrodes 110 and the overlying electron-emissive elements described below.

Each of seed strips 120 typically consists of nickel or an alloy of nickel. The thickness of the nickel layer is  $0.01 - 0.15 \mu\text{m}$ , typically  $0.07 \mu\text{m}$ . In another embodiment the seed layer consist of cobalt or an alloy of cobalt. The thickness of the cobalt layer is  $0.01 - 0.15 \mu\text{m}$ , typically  $0.07 \mu\text{m}$ . In another embodiment of the present invention, the seed strip typically consist of iron or an alloy of iron.

Upon deposition of the seed layer 120, a photo-resistive material (PR) coats on the seed

layer 120. After coating, the PR is soft baked and exposed. The PR is subsequently developed by hard baking and wet etching to conform to the contours of the surface of the glass 100.

- 5 Remaining PR maskant is stripped by methods well known in the art.

In one embodiment of the present invention, the seed layer 120 is wet etched by applying a  
10 combination of phosphoric acid, nitride acid, acetic acid and water.

Fig. 3D depicts a partial cross-sectional representation of structure 1 having undergone  
15 further steps of depositing a dielectric layer 125. As shown in Fig. 3D, a blanket dielectric layer is formed on the surface of the conductive seed layer 120 and the resistor layer 115 covering portions of the resistor  
20 layer 115 that are left uncovered by the seed layer 120.

A group of generally parallel gate electrodes 130 overlie dielectric strips 125  
25 above conductive strips 120. Each gate electrode 130 lies on the entire top surface of a corresponding one of dielectric strips 125 and, accordingly, fully overlies underlying conductive strip 120. Due to the  
30 characteristics of the etch procedures typically used to define the longitudinal side edges of strips 120 and 125, each gate electrode 130 may be slightly wider or narrower than underlying dielectric strip 125.

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Fig. 3E depicts a partial cross-sectional representation of structure 1 having undergone further steps of depositing a blanket passivation layer 135. The passivation layer 135 is disposed on the gate layer 130 and portions of the dielectric layer 125 uncovered by the gate layer 130.

The passivation layer 135 overlies the entire top surface of a corresponding one of gate layer strips 130 and, accordingly, fully overlies underlying conductive seed strip 120. In one embodiment of the present invention, passivation layer 135 may be silicon dioxide ( $\text{SiO}_2$ ), or silicon nitride ( $\text{SiN}_x$ ), or a mixture of these compounds with a  $\text{SiN}_x$ . The passivation layer 135 is subsequently masked by a PR masking agent masking the passivation layer according to a designed pattern.

After masking, the passivation layer 135 and dielectric layer 125 are etched by a dry etching method, known in the art. Remaining PR is stripped.

Fig. 3F depicts a partial cross-sectional representation of structure 1 having undergone further steps of etching the structure to create cavities for depositing the electron emission elements 140.

After depositing the passivation layer 135, the passivation layer 135, and the dielectric layer 125 are etched to create cavities or



composite openings 145 for the formation of the carbon nano-tube emitters of the present invention.

5        A patterned dielectric layer consisting of a group of laterally separated generally parallel strips 125 overlying the conductive strips 120 is formed.

10       Each dielectric opening overlies a corresponding one of conductive strips 120. The longitudinal side edges of each dielectric strip 125 are in approximate vertical alignment with the longitudinal side edges of  
15       corresponding seed strip 120.

20       In one embodiment of the present invention, the dielectric strips 125 comprises two layers of silicon dioxide and silicon nitride having a thickness of 0.5 - 2.0  $\mu\text{m}$ . In another embodiment, dielectric strips 125 comprise of a single layer of silicon-oxy-nitride having a thickness of 0.5 - 2.0  $\mu\text{m}$ .

25       The patterning of the seed layer 120 to form strips is typically performed with one or more wet etchants depending on the constituency of layer 120.

30       Gate electrodes 130 may be configured in various ways. For example, each electrode 130 can be implemented as a main gate portion and one or more thinner adjoining gate portions as described below in connection with Fig.2  
35

5 An array of rows and columns of laterally  
separated sets of electron-emissive elements  
140 are disposed on top of conductive seed  
strips 120 in composite openings extending  
10 through dielectric strips 125 and gate  
electrodes 130. Each composite opening  
consists of (a) a dielectric opening 145  
extending through one of dielectric strips 125  
and (b) a gate opening 145 also extending  
10 through overlying gate electrode 130. The top  
of dielectric opening 145 is typically the same  
as that of the gate 130 opening.

15 The carbon based electron-emissive-elements  
140 are deposited on the seed strips 120  
subsequent to the creation of cavities 145. In  
one embodiment of the present invention, a  
chemical vapor deposition (CVD) method of  
deposition may be used to deposit electron-  
20 emissive elements 140.

Each of the sets of electron-emissive  
elements 140 normally consists of multiple  
elements 140. Electron-emissive elements 140  
25 in each different set contact a portion of a  
seed strip 120 at the location where  
corresponding gate electrode 130 crosses over  
an emitter electrode 110.

30 Each set of elements 140 is electrically  
coupled through underlying seed strip 120 to  
underlying emitter electrode 110.

35 Consequently, the sets of elements 140 in  
each column of the electron-emissive-element  
sets are respectively electrically coupled

through the underlying portions of all seed strips 120 to underlying emitter electrode 110. On the other hand, the sets of elements 140 in each row of the electron-emissive-element sets are electrically coupled through portions of underlying conductive strip 120 respectively to all of emitter electrodes 110.

The electron-emissive elements 140 are typically filaments in shape, as depicted in Fig. 2. In this case, the principal constituent of elements 140 is typically carbon. Elements 140 can be shaped differently, for example, as cylindrical. Dielectric openings 145 may then be shaped differently from what is generally indicated in Fig. 2.

During field emitter operation, an anode in the light-emitting device (not shown here) situated opposite elements 140 draws the extracted electrons towards light-emissive elements located close to the anode. As electrons are emitted by each activated electron-emissive element 140, a positive current flows through underlying seed strip 120 to underlying emitter electrode 110.

Seed strips 120 provide the field emitter with electron emission uniformity and short circuit protection. Strips 120 limit the number of electrons emitted by activated elements 140. Strips 120 further prevent electron emission through just a limited number of the electron

emission elements 140. This is caused by the electrical isolation of the seed layer 120.

5 This prevents some of elements 140 from providing many more electrons than other of elements 140 at the same extraction voltage and thus prevents undesirable bright spots from occurring on the viewing surface of the flat-panel display.

10

Also, if one of gate electrodes 130 becomes electrically shorted to underlying seed strip 120 and thus becomes electrically coupled to underlying emitter electrode 110, seed strip 15 120 at the short circuit location significantly limits the current flowing through the short circuit connection. With proper electron-emitter design, the presence of the short circuit does not detrimentally affect the operation of any of the other sets of electron-emissive elements 140.

Such a short circuit can arise by way of a conductive path created through a dielectric strip 125 or by having one or more of electron-emissive elements 140 come into contact with their gate electrode 130. In the case of a gate-electrode-to-electron-emissive-element short circuit, each shorted electron-emissive 25 element 140 is normally defective.

However, the seed strips 120 limit the current through each shorted elements 140 sufficiently that non-shortcd elements 140 in 35 that set of electron-emissive elements may still operate in the intended manner. Seed

